

Sintering of Iron Ore Fines, and Raw Materials for Bhilai Steel Plant

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A detailed study has been made at the National Metallurgical Laboratory on the sintering characteristics of the iron-ores of Rajharapahar, Madhya Pradesh, and other raw materials likely to be used in the Bhilai steel plant. The effects of variables such as coke and moisture contents in sinter mix, basicity and raw material proportions, on the sintering time and their effects on the quality of sinter produced, have been studied with a sintering plant designed and fabricated at the Laboratory. Optimum conditions for producing the best sinter have been determined. Results of the tests on the Bhilai sample show that coke has a pronounced effect on sinter properties whereas moisture content directly affects permeability and sintering rate. 6.1% by weight of coke was found to be the optimum quantity for producing a good sinter. The optimum water content in the charge for producing the most permeable bed was 7%. The basicity for producing a good self-fluxing sinter in the shortest time was 0.8

PREPARATION of blast furnace burden occupies a very important place in iron smelting. It is well known that furnaces do not run to best advantage with excess of fines in the charge and for efficiency and smooth running, a uniformly sized and graded charge in the furnace is generally recommended. With many ores the problem of crushing and screening arises, after which it is necessary either to go in for agglomeration of the fines produced or to reject them. The former is usually more economical in the long run and it almost always warrants serious consideration.

Numerous methods have been suggested to solve the problem of agglomeration of ore fines, of which sintering, briquetting and nodulising or pelletising, have been tried on a large scale. Sintering, which was first developed and applied to non-ferrous ores, has proved often to be the most efficient and economical of these processes. Although the use of sinter in blast furnace burden has secondary advantages, such as higher iron production, smoother furnace operation and decreased fuel consumption, the primary object of sintering in most cases is the utilisation of blast-furnace flue dust and ore fines in such a way as to improve the characteristics of the blast furnace burden.

When agglomeration of finely divided ore into lumps or caked material is accompanied by heating, it is due to a softening—an incipient fusion without actual melting—of the fine ore, causing them to stick together. This agglomeration by means of heating

is called sintering, and the caked product is called sinter. Two types of bonding of fine ores by means of heating are possible: (i) bonding by diffusion, which is related to the process of recrystallisation in the solid; (ii) bonding by slag formation, when the glassy melt forms a matrix in which the crystalline constituents are embedded.

Diffusion is theoretically the more desirable mechanism of bonding because it results in a porous aggregate possessing good reducibility, in which iron oxides are readily accessible to penetrating gases. Haematite would be the most important diffusing agent, since it shows a relatively high surface mobility at about 1300°C. But since sinter feed contains low melting constituents also, this bonding becomes insignificant. Diffusion bond is possible in very high grade ores or concentrates.

In the case of slag bonding, a more or less liquid slag forms by fusion. All the particles remaining solid become completely embedded in the slag because of its high wetting capacity. At first only gangue minerals (lime, silica, alumina, etc.) take part in the formation of slag, but with increasing temperature, an increasing amount of iron is taken into solution. If the melt reaches a sufficiently high temperature, crystallisation of iron silicates is to be expected but at lower temperature, iron will come out of solution in the form of secondary crystals and dendrites of magnetite. All these secondary crystals, as well as any remaining primary iron-bearing constituents, are firmly enveloped by the glassy slag. The impervious and refractory nature of the latter will impair the reducibility of such a sinter.

Slag bonding does, however, produce excellent

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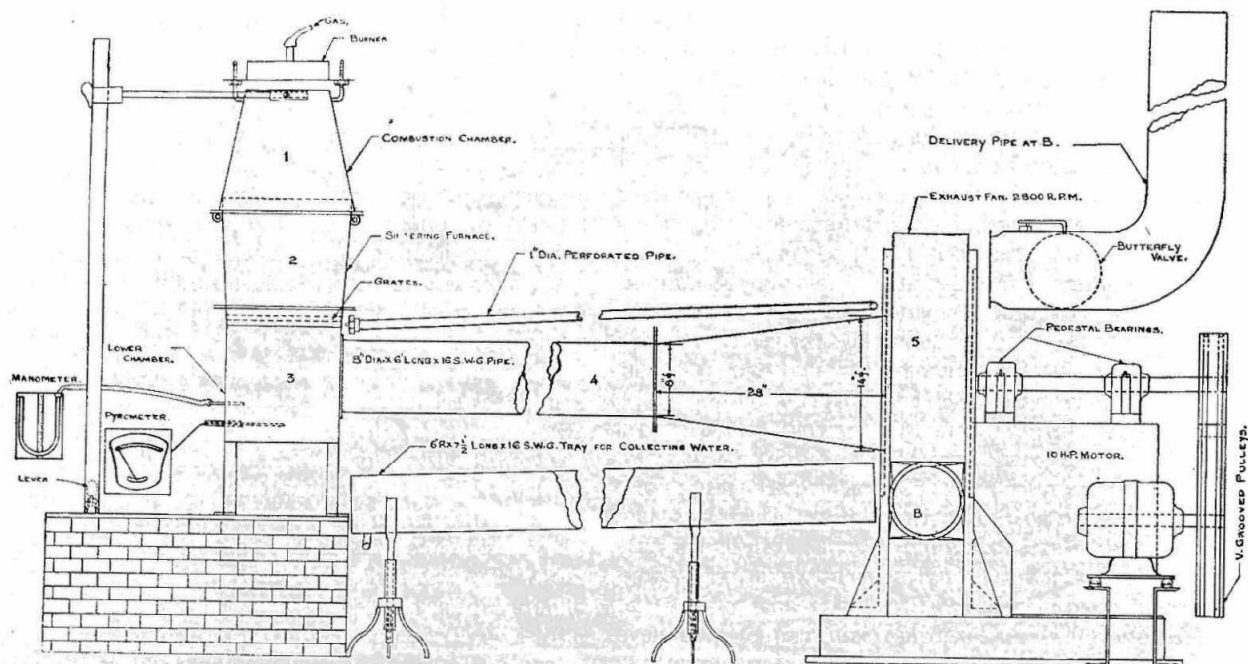


FIG. 1—Laboratory sintering plant (Batch type).

sinter strength, and it is desirable in practice to achieve a compromise between strength and reducibility. From this point of view and for the sake of fuel economy, it is desirable to produce the lowest amount of slag compatible with strength requirements. Fuel economy also demands that as little iron as possible should go into solution, that is, the amount of secondary crystals should be kept to a minimum.

The theoretical constitution of a desirable sinter can thus be stated as follows:—

1. The sinter should contain a large proportion of original unaltered grains of iron oxides.
2. The proportion of secondary crystals should be small.
3. The crystalline constituents should be

embedded in the minimum amount of slag compatible with sufficient strength.

4. The slag should be free from iron.

Sinters that have been heated insufficiently will be rich in unaltered original material. Over-

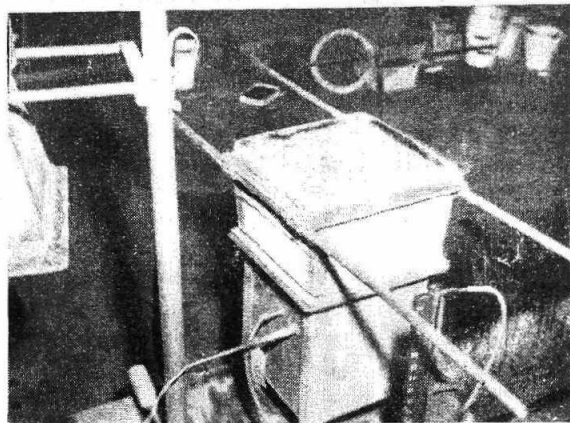


FIG. 2—Sinter box.

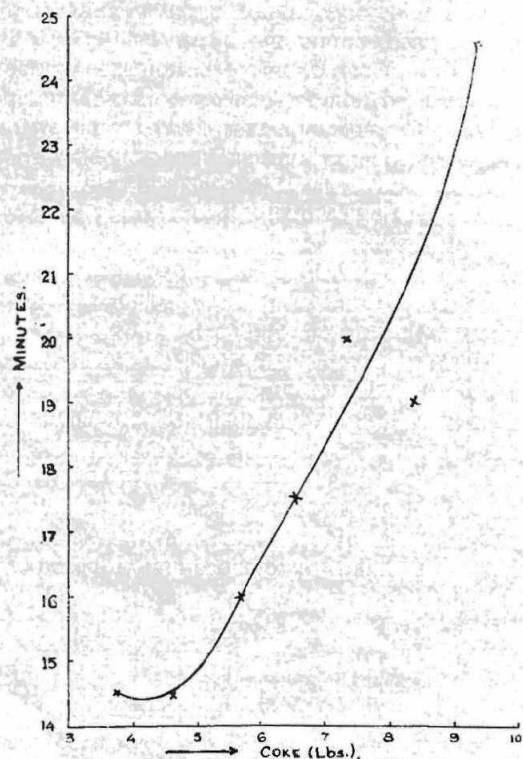
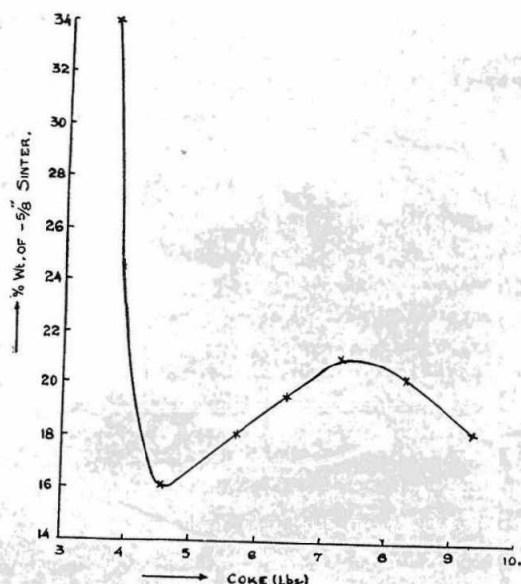


FIG. 3—Effect of varying coke content on sintering time.

FIG. 4—Effect of varying coke content on the $-5/8''$ fraction of sinter.



heated sinters will be rich in slag and secondary minerals. But the sinters that have been heated for a prolonged period without reaching very high temperature, will be relatively rich in constituents recrystallized in the solid state.

In principle, sintering consists of mixing the ore with a suitable proportion of fuel, and after igniting this, subjecting the mass to a down-draught or up-draught which is sufficient to cause vigorous combustion to take place, thus generating a temperature high enough to cause the material to frit. The actual accomplishment of sintering is brought about by the action of one or more of the following three processes:—

1. The Fe_3O_4 crystals grow together.
2. The iron oxide particles grow together as a result of the oxidation of Fe_3O_4 to Fe_2O_3 .
3. The iron oxide particles are bonded by slag.

Process 1 and 3 predominate in the formation of 'rust-burned' sinter. In the formation of 'black-burned' sinter process-2 is largely responsible, although process-1 exists before oxidation of Fe_3O_4 takes place. In rust-burned sinter, slag becomes molten and forms a bond for the iron oxide particle. Slag is localised in small areas in black-burned sinter.

The main criteria of sinter quality are freedom from fines and unsintered material coupled with strength so that it can withstand disintegration in handling and furnace load. A good sinter should be highly oxidised to facilitate reduction without exhibiting glazed surfaces and should be porous, yet free from large holes. The production of a good sinter depends to a very large extent on two main factors: (i) coke or fuel content of the charge, which controls the sintering temperature in the bed, and (ii) permeability of the bed, which controls the air-flow through the bed.

Coke has a pronounced effect on sinter properties whereas moisture exercises a direct influence

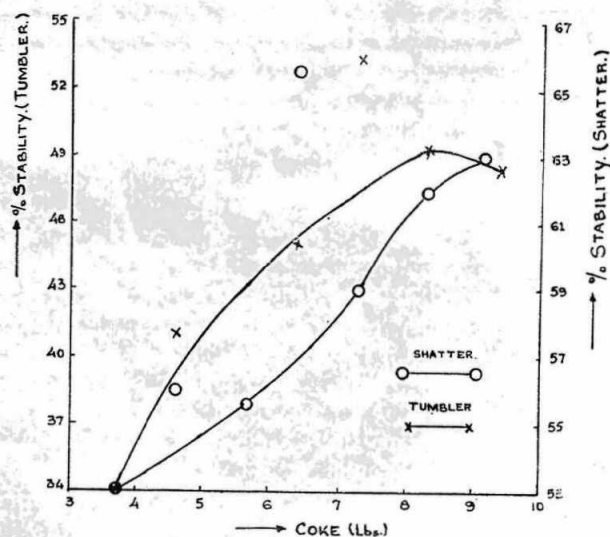


FIG. 6—Effect of varying coke content on sinter strength.

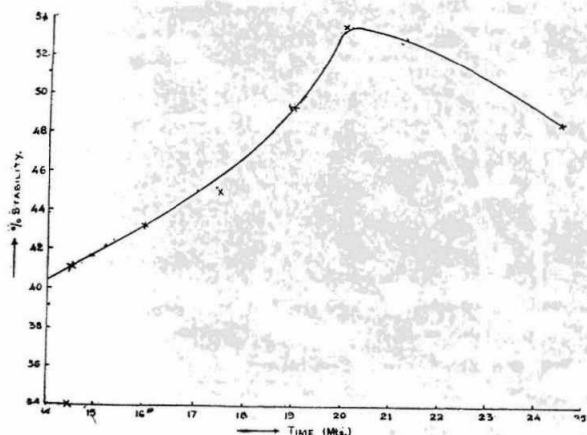


FIG. 5—Effect of sintering time on tumbler stability (coke series).

on sintering rate without affecting sinter properties. The amount of fuel required to attain the best sintering temperature is normally 6 to 7 per cent, expressed as carbon, but may be lower if the fuel is finer and uniformly disseminated in the charge. Sinter quality usually improves with increased carbon up to an optimum figure beyond which there is no improvement. Below the critical value, a soft product with much unsintered material results, while excess of carbon increases the sintering temperature, thereby melting the charge which reduces the speed of sintering and

produces a sinter characterised by large voids, glazed surfaces and absence of microporosity.

Moisture content is very important in securing proper porosity of the bed. Too much water fills up the voids in the bed giving a pasty mass and resulting in incomplete sintering. With too little water, the porous structure of the bed cannot be retained under vacuum, as compacting takes place. The principal function of moisture is the promotion of pelletizing or 'balling-up' of the feed. Given adequate mixing, size of the pellets tends to increase with the moisture content and the product shows an increasingly high air-flow for a given suction. The ultimate limit to faster sintering by improving the permeability of feed is limited. Above the permeability corresponding to the minimum air-flow necessary to maintain sintering, the sintering time decreases as the air-flow increases, first rapidly and then more and more slowly. A stage is reached beyond which increased permeability has little effect on sintering time. The feed is then so open that much of the air is drawn through the bed without making contact with the feed in the combustion zone. The texture of the feed becomes so coarse that it will not sinter thoroughly.

The grade and proportion of raw materials, their sizing, moisture content, and the method of mixing and laying the bed, are important factors affecting permeability of the bed and thereby the air flow.

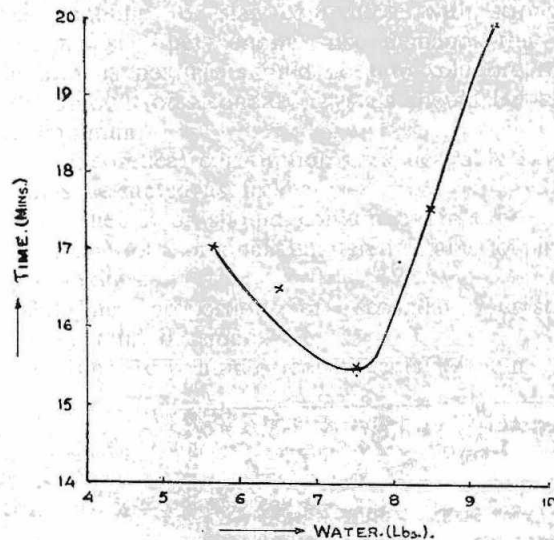


FIG. 7—Effect of varying water content on sintering time.

Additions other than ore and fuel, such as limestone, return fines, etc. are often made with a view to controlling special properties in the sinter.

Addition of limestone is advantageous in obtaining a self-fluxing sinter and reducing sintering time. Coke addition is also reduced with addition of lime. Silica in the charge will combine with lime in preference to combining with iron and thus

prevent the formation of fayalite, which is difficult to reduce in the blast furnace. However, addition of excess lime may result in the formation of calcium ferrite which is also difficult to reduce. The presence of lime in sinter mixtures which contain silica in the combined state will prevent the formation of fayalite and other iron silicates. If free silica is present, an addition of lime will prevent

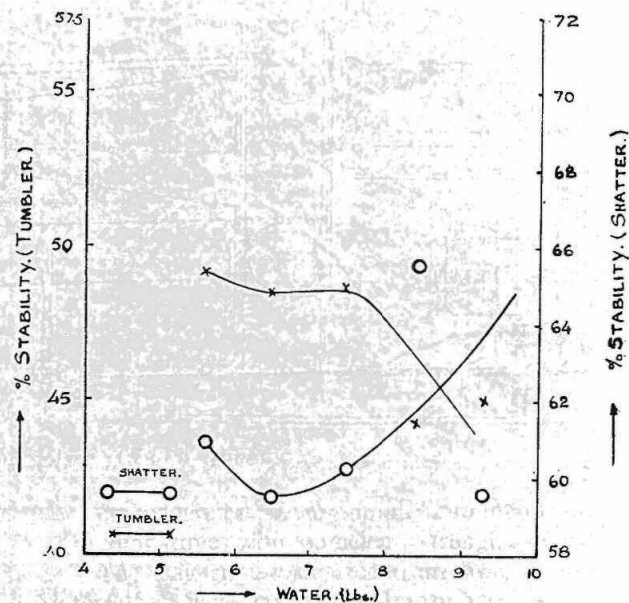


FIG. 8—Effect of varying water content on sinter strength.

the formation of fayalite but a mixed calcium-iron silicate is formed. The addition of lime to mixtures which are difficult to sinter, is more beneficial than increase in fuel addition. Lime speeds the process, whereas more fuel merely raises the peak temperature reached by the sinter. The addi-

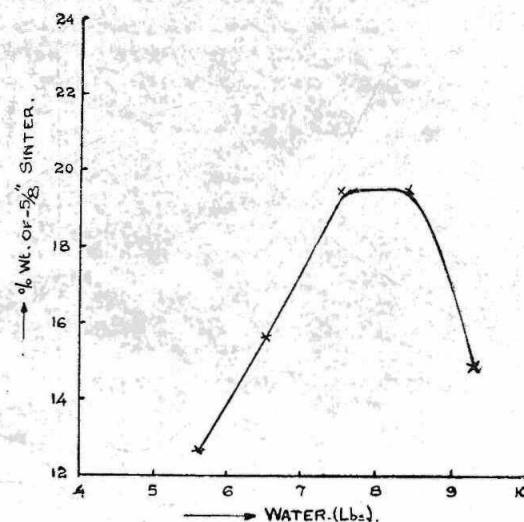
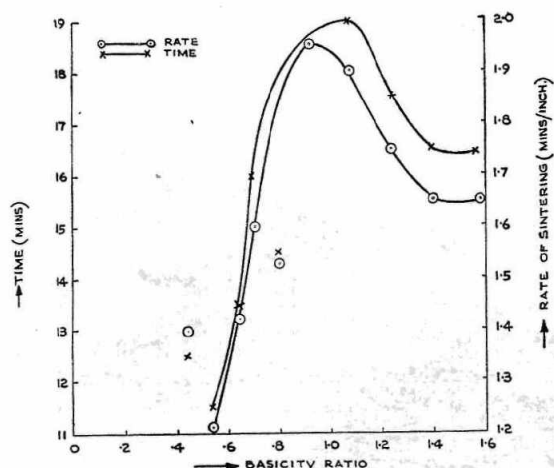


FIG. 9—Effect of varying water content on the -5/8" fraction of sinter.

FIG. 10—Effect of varying basicity on time and rate of sintering.



tion of lime, therefore, may be regarded as useful both for increasing the rate of production and for improving sinter quality.

In the lay-out of a sinter plant, it is usual to permit some unsintered material to persist, the circulating load in the form of sinter fines being dictated by the amount of fines which are inevitably and ultimately produced after screening the coarse sinter for the blast furnace. As addition of sinter fines increases the porosity of the mix, the sintering time is reduced to some extent by giving a better permeability to the bed.

Thus, the quantity of fuel, moisture content, screen analyses and grade of the products forming the charge, method of mixing the charge, loose and uniform charging, simultaneous and uniform ignition and plentiful supply of air are matters which must be rigorously defined to control sintering. Measurement of waste gas temperature, suction and temperature gradient of the bed pro-

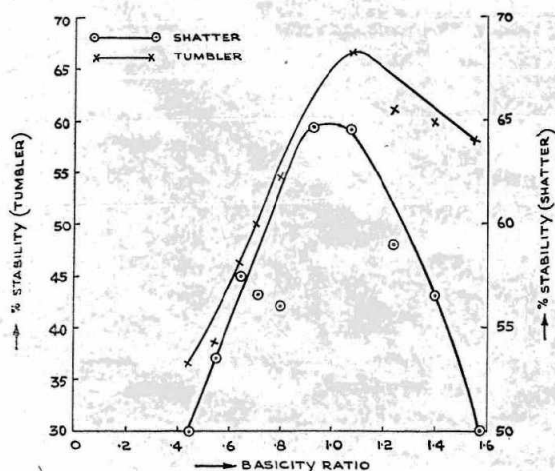


FIG. 11—Effect of varying basicity on sinter strength.

vides means of following the conditions in the charge during sintering.

The end point of sintering in the Laboratory unit can be defined as the time at which the waste-gas temperature reaches a maximum. Dissection of beds in which sintering has been stopped before completion, shows that the combustion is at any given moment limited to a rather thin layer, rarely more than $\frac{1}{4}$ inch thick. This combustion zone or flame front rests on unburnt feed, and above it there is a layer of sinter, red-hot near the flame front and progressively cooler towards the top of the bed.

SINTERING IRON ORE FINES FOR BHILAI

A detailed study has been made at the National Metallurgical Laboratory on the sintering characteristics of the iron ores of Rajharapahar, Madhya Pradesh and other raw materials likely to be used in the Bhilai Steel Plant. Optimum conditions for producing the best sinter have been determined with the help of a sintering plant designed and fabricated in this laboratory.

As desired by the Russian engineers, the sintering experiments were carried out on the basis of stipulated commercial formulae which included quantities of manganese ore, blast-furnace flue dust and mill-scale as well as iron ore fines, coke

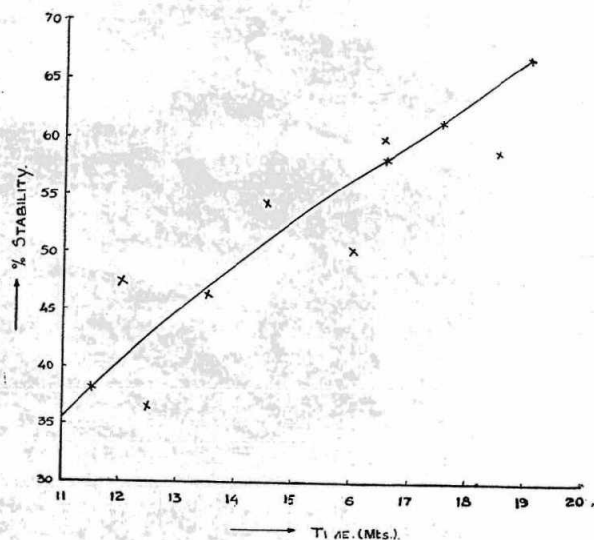


FIG. 12—Effect of sintering time on tumbler stability (basicity series).

and limestone. Three varieties of iron ore viz., massive, laminated and lateritic were received. However, considering the poor grade of laterite ore received and the high proportion of this material required to be used in the sinter, and as it was felt that the lateritic ore production was bound to decrease once mining had reached a depth of 30 feet or so, tests were also performed with varying quantities of laterite.

Samples of flue dust, mill scale and coke breeze

required for the tests were received through the courtesy of the Tata Iron & Steel Co., whereas the remaining raw materials were received from regions from where the Bhilai Plant is going to get their supplies.

Physical tests for sinter.—As no standard tests have been laid down for determining the strength of sinter, the shatter and tumbler tests recommended by the A. S. T. M. standard for coal were employed for testing the sinter obtained during the present investigation as desired by the Russian engineers.

For the shatter test, 40 lb. of $-4'' + 1\frac{1}{2}''$ sinter was dropped twice from a height of 6 ft on to a M. S. Plate. The shattered product was sieve analysed to find out the size stability and the percentage weight of $-\frac{1}{4}''$ material produced.

For the tumbler test, two 1000 gm. lots of the $-1\frac{1}{2}'' + 1''$ (square hole sieve) fraction of the sin-

ter already subjected to shatter test, were tumbled separately for 1 hour at the rate of 40 r.p.m. The tumbled products were sieve analysed and the size stability was calculated by the A. S. T. M. method. The mean of the two values was taken as the tumbler size stability of the sinter.

Though the quality of sinter is also governed by its reducibility and percentage of magnetic fraction it contains, these two tests could not be carried out for want of time.

RAW MATERIALS

Iron ore.—Three types of iron ore viz: massive, lateritic and laminated varieties from the Rajharapahar deposits, Madhya Pradesh, were received from the Indian Bureau of Mines. The samples were crushed to $-5/8''$ size. The sieve and chemical analyses of the samples are given in Tables I and II.

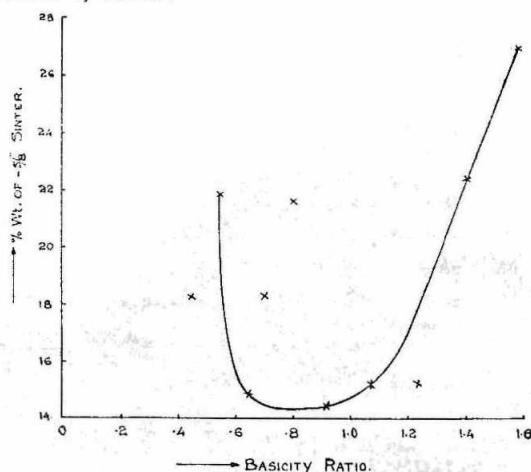
TABLE I—SIEVE ANALYSES OF CRUSHED RAW MATERIALS

Size	Weight, per cent				Mill-scale	Coke	Lime-Stone No 1 : No 2 :		Flue dust
	Massive Iron Ore	Lateritic Iron Ore	Laminated Iron Ore	Manganese Ore					
$+ 0.371''$		15.1	11.5						
$- 0.371'' + 2\frac{1}{2}$ mesh		9.9	12.7						
$- 2\frac{1}{2}$ mesh $+ 3''$	16.7	12.4	11.2	19.0	24.2				
$- 3'' + 4''$	17.6	19.7	19.7	18.6	29.2				
$- 4'' + 6''$	13.2	14.2	11.2	12.0	18.7				
$- 6'' + 8''$	9.5	9.5	7.7	7.3	9.4				
$- 8'' + 10''$	8.6	6.5	5.8	6.0	5.5	18.8			
$- 10'' + 20''$	10.8	6.3	5.7	8.1	5.7	29.5	34.5	35.5	1.1
$- 20'' + 28''$	4.9	2.2	3.1	4.1	2.0	11.6	17.9	17.2	1.6
$- 28'' + 35''$	3.8	1.3	2.2	3.7	1.4	9.4	10.7	11.3	7.7
$- 35'' + 48''$	3.3	0.8	2.1	3.8	1.0	7.5	10.8	8.5	16.5
$- 48'' + 65''$	2.4	0.5	1.6	3.1	0.8	5.2	6.4	6.0	19.5
$- 65'' + 100''$	2.3	0.4	1.6	3.6	0.8	4.8	5.8	4.5	21.5
$- 100'' + 150''$	{ 6.9	1.2	3.9	10.7	1.3	4.5	2.6	3.2	7.2
$- 150'' + 200''$						3.7	1.8	2.0	13.2
$- 200''$						5.0	9.5	11.8	11.7
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE II—CHEMICAL ANALYSES OF RAW MATERIALS

Raw Material	Assay per cent					Others
	Fe	SiO ₂	Al ₂ O ₃	CaO	MgO	
Iron ore :						
massive	52.34	8.67	6.85	0.34	0.36	
lateritic	43.46	14.55	14.91			
laminated	52.53	9.26	8.54			
Manganese ore	8.64	13.69	3.51	3.37	2.80	Mn, 41.50 ; (MnO ₂ , 26.50) ; Ba 1.18
Flue dust	36.00	13.01	10.56	4.40	trace	Moisture 0.82 ; L. O. I. 19.58
Mill scale	73.80	0.51				FeO, 59.82 ; Fe ₂ O ₃ , 38.90
Coke		12.02	7.08	0.99	0.69	Fixed C, 72.33 ; Ash, 24.60 ; Vol. met. 1.94 ; Fe ₂ O ₃ , 3.32 ; Moisture 1.13
Limestone No : 1		13.79	3.73	41.39	2.35	L. O. I. 34.62
„ No : 2		3.79	0.66	49.26	2.64	L. O. I. 41.89

FIG. 13—Effect of varying basicity on the $-\frac{5}{8}$ " fraction of sinter.



Manganese ore.—The manganese sample received from the Indian Bureau of Mines was crushed to $-\frac{3}{8}$ " size and the crushed sample had the sieve and chemical analyses as given in Tables I and II.

Flue dust.—Since no blast furnace flue dust arising from the Bhilai Steel Plant will be available for some years, it was decided to use flue dust received from the Tata Iron & Steel Co. Ltd. Tables I and II include the sieve and chemical analyses of this product.

Mill scale.—For the same reason as given above, a sample of mill scale was also obtained from the Tata Iron & Steel Co. Ltd. The sample which was crushed to $-\frac{3}{8}$ " size had the sieve and chemical analyses as given in Tables I and II.

Coke.—The sample of coke was also received from the Tata Iron & Steel Co. Ltd. and after

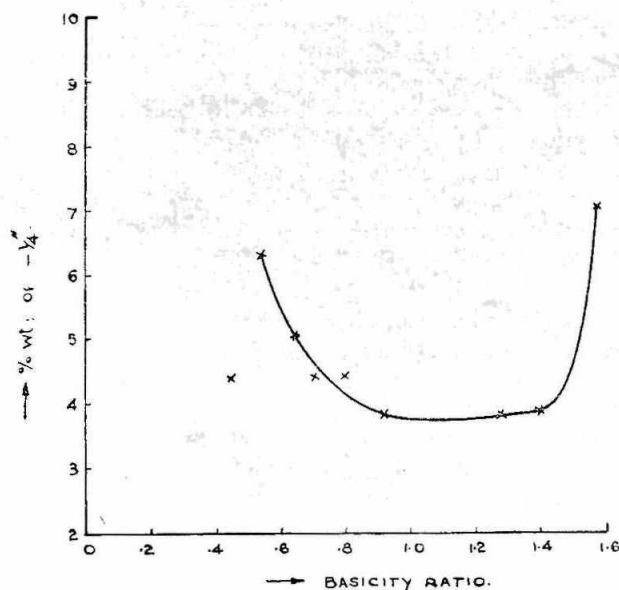


FIG. 14—Effect of varying basicity on the $-\frac{1}{4}$ " fraction after shatter test..

crushing it to $-\frac{8}{8}$ mesh size had the sieve and chemical analyses as given in Tables I and II.

Limestone.—Two samples of limestone were received from the Indian Bureau of Mines. Since the quantity of the first sample received was inadequate for the entire investigation, a second sample (No. 2) was subsequently obtained. The samples were crushed to $-\frac{10}{10}$ mesh size. The sieve and chemical analyses of the two samples are also included in Tables I and 2. The first sample of a comparatively low grade, was used for the earlier tests in which the coke and water contents were varied. The second sample was of a higher grade and was used for the subsequent tests. Due to the difference in grades between the two samples, a smaller quantity of sample No. 2 was sufficient for maintaining the same basicity, as compared to sample No. 1.

EXPERIMENTAL PROCEDURE

Laboratory sintering unit.—The tests were carried out in a Laboratory sintering unit illustrated in Figs. 1, and 2. It consists (Fig. 1) of a combustion chamber with gas burner (1), a sinter box (2) with two cast iron grates one above the

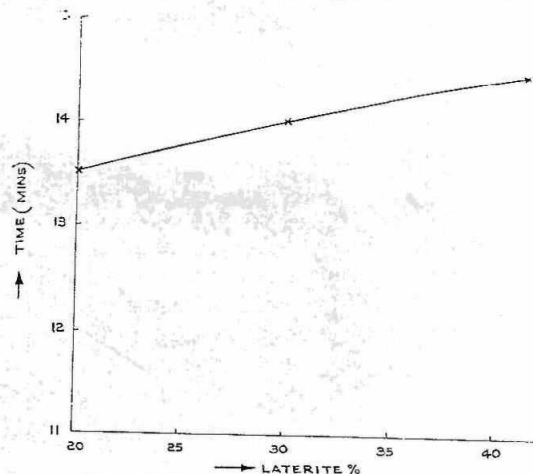


FIG. 15—Effect of varying laterite content on sintering time.

other; the grate-area being 1 ft. square, and a lower chamber (3). The lower chamber was connected through a pipe (4) to a suction fan (5), having a capacity of 1350 cu ft of air per minute at N. T. P. The fan was driven by a 10 h. p. motor.

Composition of the charge.—In most of the experiments, the sinter mix was made up of the following raw materials in proportions given in Table III. Coke, water, and limestone were added in varying quantities.

For most experiments the following methods of mixing and preparing the bed was adopted. Various raw materials with required quantity of limestone to give the desired basicity ratio and varying quantities of water were weighed out and

TABLE III—COMPOSITION OF THE CHARGE

Raw Material	Weight %	Remarks
Iron Ore	66.6	Massive : Laterite :
Manganese Ore	1.2	Laminated = 3.6 : 41.3 : 55
Flue Dust	6.2	
Mill Scale	2.5	
Sinter Fines	23.5	

mixed thoroughly in a concrete mixer. Ten pounds of the mix were removed to form the bottom layer (about 1" high) of the charge in the sinter box. The required quantity of coke was then mixed thoroughly with the remaining charge in the mixer. Ten lbs of this mix was kept separately and the remainder evenly and loosely filled into the sinter box. One additional pound of coke was thoroughly mixed with the 10 lbs of the mixed charge kept aside earlier to form the top ignition layer in the sinter box. Thus the sinter bed consisted of three distinct layers of material with varying quantities of coke, (i) the bottom 1" layer without coke, (ii) the middle layer 7"—8" thick with medium quantity of coke and (iii) top 1" layer richer in coke to facilitate ignition.

The total weight of the charge in the sinter box was usually about 100 lbs.

Ignition.—The local coke oven gas employed

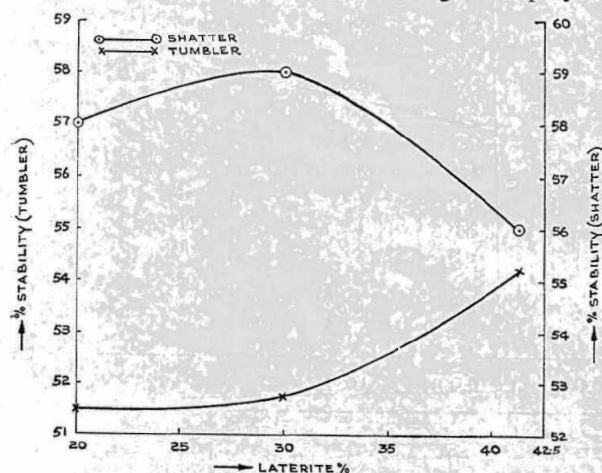
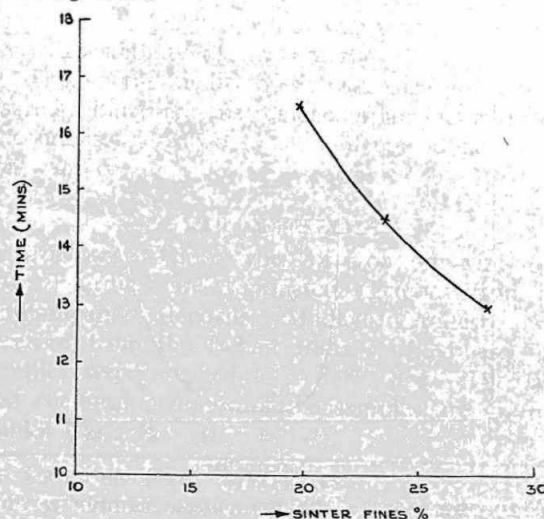


FIG. 16—Effect of varying laterite content on sinter strength.

for igniting the sinter bed. The ignition time was 2 min. and the gas pressure during ignition was maintained at 6" water gauge. The suction during ignition was kept between 4" and 7" water gauge, as measured by means of a water monometer connected to the lower chamber by rubber tubing.

Sintering.—After ignition, the ignition chamber was swung aside and the suction was increased to about 20" water gauge by fully opening the butterfly valve in the delivery pipe connected to the exhaust fan. The suction dropped to about 15" water gauge, when sintering was completed. The temperature of the exit gases at a point just below the furnace grates was measured by means of a

FIG. 17—Effect of varying sinter fines content on sintering time.



chromel-alumel thermocouple. The temperature of the exhaust gases gradually attained a maximum temperature and then started to fall. The sintering was assumed to be complete just when the temperature of the exhaust gases started to decrease.

The sinter was air-cooled, weighed and then broken to -4" size (round hole sieve) for the shatter and tumbler tests.

EXPERIMENTAL RESULTS

Effect of varying the coke content on sintering.—The following tests were performed to study the effect of variation of coke content on sintering. The charges for these tests are given in Table III.

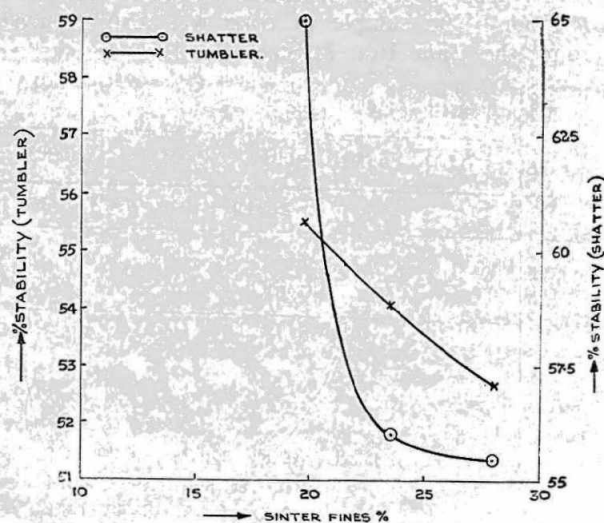


FIG. 18—Effect of varying sinter fines content on sinter strength.

The required quantity of limestone was added to maintain the basicity ratio $\frac{\text{CaO} + \text{MgO}}{\text{Al}_2\text{O}_3 + \text{SiO}_2}$ at 0.54.

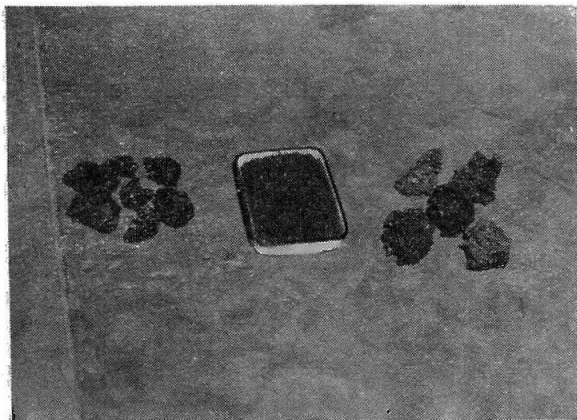


FIG. 19—(left) *Non-porous sinter, basicity 1.57*; (centre) *Mix for sintering*; (right) *Highly porous sinter, basicity 0.8*.

Water content of the mix was 8.2% and coke was varied from 3.67 to 9.18 lbs per 100 lbs of the charge. The results are shown in the graphs, Figs. 3 to 6.

Fig. 3 shows that sintering time increased with increasing quantity of coke. With lesser quantity of coke, the amount of unsintered material was high, indicating that the quantity of fuel was insufficient to give the proper sintering temperature. Variation in the coke content did not appreciably increase the amount of sinter fines produced (Fig 4). Although the strength of sinter increased with higher coke content (Figs. 5 and 6), sinters produced with more than 7.34 lbs. coke were characterised by large voids, glazed surfaces and absence of micro-porosity. The size stability of the sinter as indicated by the shatter and tumbler tests, was fairly high when a coke content of 6.42 lb. (i.e. 6.5% of the mix) was employed. Although the sintering time was lower with lesser quantities of coke, the sinter strength was also comparatively low.

Effect of varying moisture content.—This series of tests was performed with varying water contents from 5.61 to 9.35 lb/100 lb. of charge and the coke was maintained at the apparent optimum value of 6.5%.

The basicity was kept as before at 0.54 by requisite addition of limestone. The results are shown in Figs. 7 to 9.

Sintering time was found to decrease as the water content was increased upto 7.48 lb but with higher water contents, the sintering time again increased indicating that the optimum range was between 6.54 and 7.48 lb water per charge, equivalent to between 6.1% and 7.0% of moisture in the mix (Fig. 7). The shatter and the tumbler tests indicated that the sinter strength was almost constant when the moisture content was between 5.61 lb. and 7.48 lb per charge (Fig. 8). The amount of sinter fines ($-\frac{5}{8}$ ") produced is given in Fig. 9.

Effect of varying basicity on sintering.—This series of tests was performed changing the basicity of the charge by addition of limestone, but maintaining coke and water contents at the optimum values obtained earlier viz. 6.1% and 7.0% respectively of the mix. The basicity ratio was varied from 0.44 to 1.57 to determine the optimum ratio when a good self-fluxing sinter could be produced. The charge consisted of raw materials in the same proportion as given in Table III. Figures 10 to 14 show the results of this series of tests.

The sintering time as well as the strength of the sinter increased with increase in the basicity ratio upto 0.92 but both decreased with higher basicity (Figs. 10, 11 and 12). The $-\frac{5}{8}$ " material obtained after breaking the sinter to -4 " size and the $-\frac{1}{4}$ " material obtained after shatter test of the sinter remained almost the same, the average for the latter being about 4% in the basicity range between 0.64 and 1.24 (Figs. 13 and 14). It is reported that according to Russian practice, the $-\frac{1}{4}$ " material produced after the shatter test should not exceed 5% by weight, for a good sinter. Taking into consideration both strength and sintering time, a basicity of 0.8 was considered to be the optimum for a self-fluxing sinter. With addition of the coke to blast furnace for reduction of the sinter basicity of the slag is expected to be lowered to about 0.7. Although the deterioration in strength of sinters obtained at higher basicities than 1.07 was not very marked, such sinters were characterised by large voids, glazed surfaces, and absence of porous structure (Figs. 19 and 20).

There was no appreciable improvement either in sinter strength or in sintering time when slight variation in coke and water contents were made for producing a sinter of basicity 0.8.

A sinter produced without limestone showed a fairly good strength. The time of sintering was also reduced slightly.

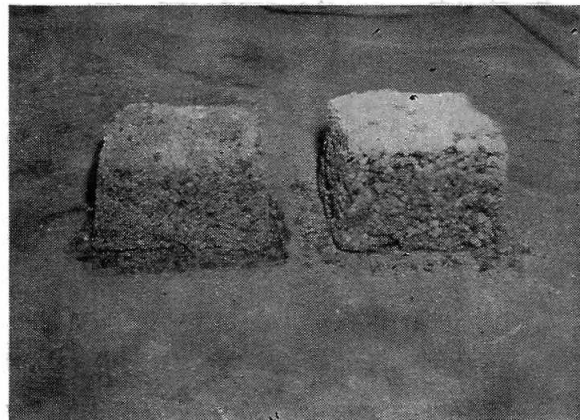


FIG. 20—(left) *Good porous sinter, basicity 0.8*; (right) *Sinter with large voids showing tendency to melt, basicity 1.57*.

Figs. 21 and 22 show photo-micrographs of two sinters with 0.8 basicity and with no limestone respectively. In Fig 21, haematite (H) is being replaced by magnetite (M) along the grain boundaries. Photo-micrograph of sinter without limestone (Fig 22) shows skeleton crystals of magnetite with dendritic structure embedded in slaggy matrix.

Table IV shows the chemical analyses of a few sinters with different basicity ratios.

TABLE IV—CHEMICAL ANALYSES OF A FEW SINTERS WITH 41.3% LATERITIC VARIETY IN THE IRON ORE AND 23.5% RETURN SINTER FINES.

Constituents	Sinter without Limestone	Sinter with 0.54 Basicity	Sinter with 0.8 Basicity	Sinter with 1.57 Basicity
Total Fe	53.41	43.89	43.25	35.30
FeO	23.45	12.43	9.50	5.95
CaO	trace	13.55	16.09	27.20
MgO	trace	1.20	1.70	1.98
SiO ₂	12.99	13.54	12.14	11.70
Al ₂ O ₃	10.82	10.20	8.14	8.26
P	0.11		0.102	
S	0.06			
Calculated Basicity		0.61	0.91	1.50

EFFECT OF OTHER VARIATIONS

Lateritic content.—Variations in the lateritic ore content of the charge at 0.8 basicity indicated that the time of sintering increased with higher laterite content in the charge, although there was no appreciable change in the sinter strength (Figs. 15 and 16). Lesser quantities of laterite and no limestone in the charge produced sinter of slightly lower strength,

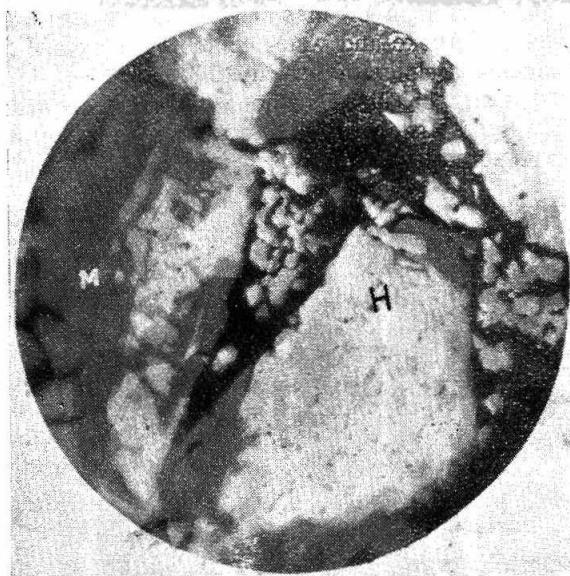


FIG. 21—Photomicrograph showing haematite (H) being replaced by magnetite (M) along the grain boundaries. [Vertical illumination—oil immersion objective— $\times 538$.]

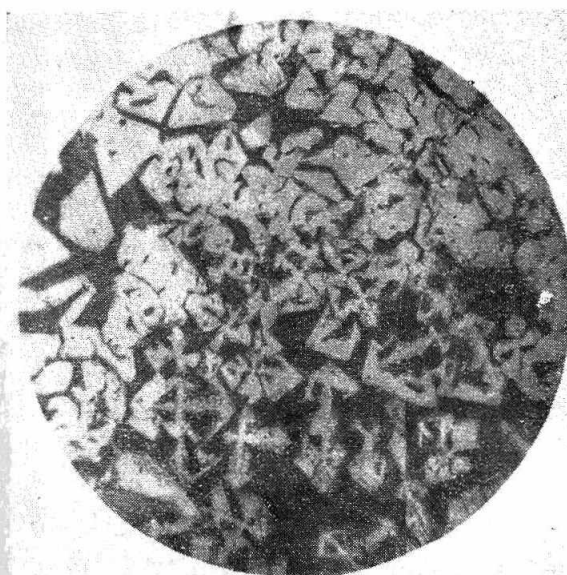


FIG. 22—Photomicrograph showing skeleton crystals of magnetite with dendritic structure embedded in slaggy matrix. Edges of crystals are more prominently developed than the interior of the crystal face. [Vertical illumination— $\times 106$]

but the time of sintering was reduced considerably. This indicated that in case a self-fluxing sinter was not required, reducing the amount of lateritic ore in the charge would result in production of a sinter of fairly good strength in a much shorter time.

Return sinter fines.—Increase in the sinter return fines charge decreased the sintering time (Fig. 17). This was due to the higher porosity of the charge with increased amounts of sinter fines. The strength, however, decreased slightly with more sinter fines (Fig. 18).

Suction.—Sintering performed with a lower suction increased the time of sintering. This was due to the decreased air-flow through the bed and consequently slower rate of burning of coke.

By employing full suction at about 20" water gauge during ignition also, the sintering time was reduced slightly. Variation in suction did not appear to have an appreciable effect on sinter strength.

Variation of coke in the bedding layers.—For the same coke content of 6.14% in the mix, the method of sprinkling 0.25 lb (4% of the total coke) on the top, increased the sintering time as compared to the standard procedure employed in the earlier tests of maintaining a 1" top layer rich in coke. This was presumably due to the increased coke content of the middle layer of the bed obtained by the former method. The sinter strength remained the same in both the cases. But with

[Continued on page 303]

A high proportion of ore can be added, which is largely recovered since the slag iron at this stage is only 3%. The final temperature is approximately 1600°C.

Although most of the Indian iron has a medium phosphorus content, the method may be of value for pretreatment since metal of low metalloids content but high in temperature would be available for the open hearth furnace.

CONCLUSIONS

It has been shown that even low grade fuels, such as lignites and brown coal, can be used as fuels in low shaft furnaces. The role of oxygen is not yet clearly defined in the smelting of iron, but there are indications that its use may be economical.

For ferro-alloy production, the case for using a low shaft furnace and a blast enriched with oxygen is much stronger.

Recent American tests have indicated that oxygen enriched air may be advantageous and economical in conventional blast furnaces. Experiments are envisaged in Great Britain with the object of investigating the effect on blast furnace practice.

In a country possessing limited scrap resources, the use of high hot metal charges in the open hearth furnaces is most important. Substantial reduction in the metallurgical load, under such conditions, can lead to decided economic gains by reducing slag volume, fuel consumption and improving heat transfer. The shorter dwelling time reduces refractory wear and gives higher output rates. There appears to be a sound economic case for pretreatment to remove silicon in Indian open hearth shops.

The removal of phosphorus is not so important at the present time, but two methods have been mentioned which may prove useful even under existing conditions, and would most certainly be of advantage should it become necessary to use high phosphorus ore.

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full suction right from the start of ignition and with even a lower coke content of 5.3% and 0.25 lb coke sprinkled at top, the sintering time was slightly lower than with the standard bedding procedure. This procedure has the advantage of simplicity in the mixing and bedding procedure.

CONCLUSIONS

Coke has a pronounced effect on sinter properties. The sintering rate decreased with higher coke content. For the Bhilai iron ore fines, 6.1% of coke was found to be the optimum quantity for producing a good sinter if the bed was made in three layers, viz. 1" bottom with no coke, 7"-8" middle with medium coke and the top 1" layer, high in coke. The suction during ignition was low and was raised to about 20" w.g. during sintering.

Equally good results were obtained with a simplified mixing and bedding procedure with an even lower amount of coke (5.3%) viz. 1" bottom layer with no coke, the remaining 8"-9" containing all the coke, except about 4% (of the total coke content) which was spread on the surface to facilitate ignition. This method required full suction right from ignition.

Moisture content has a direct influence on sintering rate but essentially no influence on sinter properties.

The optimum water content in the charge for producing the most permeable bed was 7%.

The basicity for producing a self-fluxing sinter of good strength in the shortest time was 0.8. Sintering time as well as the strength of the sinter increased with increase in the basicity ratio upto 0.92, but both decreased with higher basicity.

Sintering time decreased as the laterite content of the mix decreased, the strength of sinter remained almost the same, and the sintering time varied inversely with suction.

The strength of sinter in most cases was directly proportional to the sintering time, under a given set of conditions.

The sinters produced during the tests were found to be strongly magnetic containing mostly magnetite and some haematite embedded in slaggy matrix.

As desired by the Russian engineers, only shatter size stability, percentage weight of $\frac{1}{4}$ " size sinter after shatter test and tumbler size stability, were determined to evaluate the sinter quality. Though reducibility, porosity, bulk density and percentage of magnetic fraction also govern the quality of sinter, these could not be determined with in the time available for the investigation.